Comparison of 3D point cloud quality based on image data acquired with various UAV- and camera systems from low cost to professional

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The Background

- Paramount goal of EO: Collect data to boost understanding of biophysical processes and relationships on earth for making wise decisions
- Data collection should include all means of observations: *in situ*, unmanned aerial vehicles (UAV), airborne, spaceborne, citizen scientists
- E.g. low cost drones piloted by citizens have great potential to supplement need for 3D data

Fig.1. Scheme of integrative EO including observations based on in situ measurements, UAVs, planes, satellites, citizen scientists.

The Experiment

- 7 UAVs / 9 camera systems (survey to toy level)
- Optimal acquisition conditions on 01.11.2018: diffuse light, no wind
- Flight altitude: 100 m over ground
- Image overlap 75% along and across track nominal
- Exposure time < 1/320 s to prevent motion blur

Reference data

- LiDAR data (2014), 13.5 points/m²
- 8 GCPs surveyed with RTK GNSS

Fig.2. Reference target.

The Testsite Jenaer Forst

- 2 km to the West of Jena, Germany
- Flat terrain, dimensions: 800 m x 350 m
- Various land cover: e.g. forest, buildings, grassland, paved and gravel roads, water

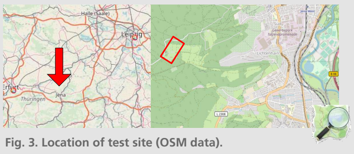


Fig. 3. Location of test site (OSM data).

Fig. 4. 3D point cloud of test site delineated based on DJI Mavic Pro 2018 imagery.

Data Processing

- Delineation of orthomosaics and dense point clouds [high] (Agisoft Metashape 1.5.1)
- Each UAV datasets was processed three times:
  1.) Using on-board GNSS data only,
  2.) Using the 3 exterior GCPs only,
  3.) Using all 8 GCPs
- No manipulation of original image data

	Sony 7 R 35 mm	DJI Phantom 4P Pro	DJI Mavic 2016
# camera pixels	7360 x 4912	5472 x 3648	4000 x 3000
# images acquired	516	200	380
# images aligned	516	189	359
# points	667,158,869	177,342,850	160,768,494
# points per m²	2216	664	480
Ground resolution	1.47 cm	2.45 cm	2.98 cm
Pixel spacing orthomosaic	1.5 cm	3 cm	3 cm
Total processing time	ca. 30 h	ca. 4.5 h	ca. 6.5 h

Tab. 1. Camera, Data and Product parameters for three cameras.

Fig. 5. Samples of imagery for the nine different camera systems: GCP Teflon panel – high contrast, graffiti on roof – low contrast, tiles on roof – fine scale texture.

Results

	Error X [m]	Error Y [m]	Error Z [m]
Sony R7 – GNSS	1.467	2.422	1.249
Sony R7 – GNSS + 3 GCPs *	0.033	0.019	0.879
Sony R7 – GNSS + 8 GCPs	0.020	0.009	0.004
Phantom P4 – GNSS	3.569	1.021	17.633
Phantom P4 – GNSS + 3 GCPs *	0.124	0.531	0.719
Phantom P4 – GNSS + 8 GCPs	0.004	0.004	0.009
Mavic 2016 – GNSS	1.245	0.982	18.879
Mavic 2016 – GNSS + 3 GCPs *	0.175	0.455	0.620
Mavic 2016 – GNSS + 8 GCPs	0.002	0.002	0.005

Tab. 2. Absolute location accuracy (RMSE) for the three processing/georeferencing levels. The large Z-errors for DJI drones using onboard GNSS data only is caused by erroneous altitude readings (solvable). * Improved camera calibration using 8 GCPs results in lower location errors (XYZ < 0.2 m)

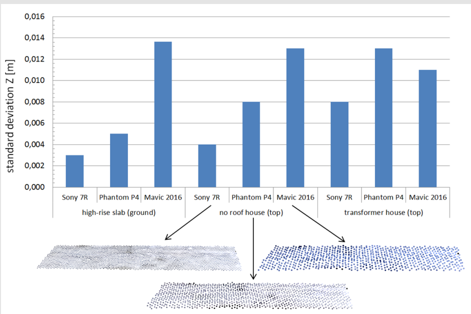
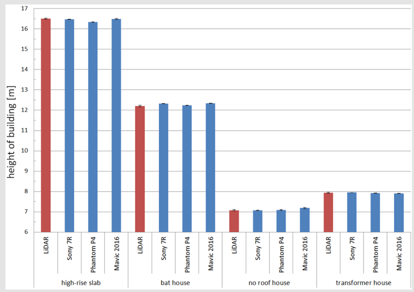


Fig. 8. Dispersion of Z (noise) over smooth and planar surfaces



Figs. 6, 7. Assessment of relative height accuracy (relevant for nDSM). Computation of ΔZ for four different buildings and comparison to LiDAR.

Summary of preliminary results & outlook

- Low cost UAV image data can be used for orthomosaic and point cloud generation
- Without GCPs 2D (XY) geolocation accuracy was better than 5 m (for low cost UAVs)
- Without GCPs Z offset of model was close to 20 m (for low cost UAVs)
- 3 GCPs were not sufficient for sound camera calibration (flat terrain, single scale nadir images)
- Delineated relative heights (building heights) in good agreement with LiDAR (ΔZ < 10 cm) → generation of precise nDSM feasible
- Small σ (< 1.4 cm) of Z values over smooth and planar surfaces for all cameras – low cost cameras show larger σ
- Future Work: Elaboration of camera calibration scheme suited for CS (external pre-calibration/self calibration using suited image data)
- Analysis of remaining data, extension of analysis…

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